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Engineering Plastics

Competition mounts as products proliferate /Page 21

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News of the Week

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■ **France's Air Liquide, world's largest industrial gas supplier, offers to buy Houston-based Big Three Industries.** **Page 5**

■ **House votes to hold off production of binary chemical weapons until 1987.** **Page 5**

■ **NASA selects new design for space shuttle booster rocket to eliminate problems that caused the *Challenger* explosion.** **Page 5**

■ **NAS report on air quality inside commercial airliners recommends ban on smoking in domestic flights.** **Page 6**

Cover: Surgical trays are one of newest uses of polysulfone. Photo courtesy of Amoco Chemicals

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Government

House clears majority of fiscal 1987 R&D appropriation bills; no trend in funding allocations is discernible, but several agencies would receive more R&D funds than this year. **Page 11**

Science

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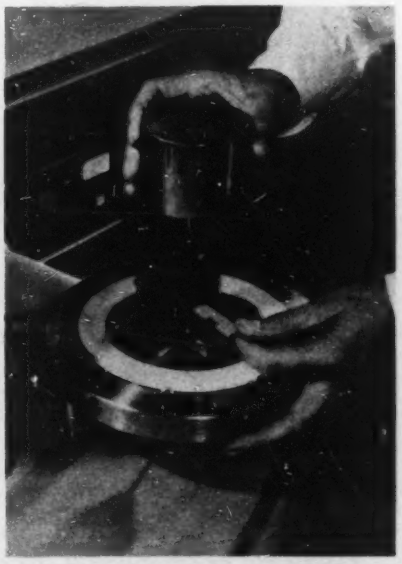
Books

In "The Chemist's English" a set of witty essays offers practical advice on problems that confront chemists when they write research papers and reports. **Page 49**



Product Report

The engineering plastics industry of the 1980s is characterized by proliferation of products as well as by increased competition. **Page 21**

House Passes Fiscal 1987 R&D Appropriation Bills

Funding levels allotted to federal agencies show no trend when compared with Administration request or last year's funding level

The House has cleared fiscal 1987 R&D appropriation bills for most federal agencies. The Department of Defense is the major exception. Those bills are the vehicles used to tell federal departments and agencies just how much money they actually have to spend in any given fiscal year. It's hard to discern any overall trend for R&D in House action to date, and the Senate may well have different priorities.

The House has set the 1987 budgets for some R&D programs at levels that are below both fiscal 1986 funding and the Administration request for 1987. Other programs are funded below 1986 levels but above the request; still others are above 1986 levels but below the request. And the House has set funding for some R&D programs that is up from both 1986 funding and the Administration request.

A good example of programs in the latter category are those of the National Institutes of Health, for which the Administration had requested an overall decrease of about 4%. The House went in the opposite direction, approving a 1987 budget of $6.2 billion for NIH, 17% above fiscal 1986 funding and 21% more than requested, with all of the individual institutes sharing the largesse. The Appropriations Committee directed that the monies in the bill should be used to fund full direct and indirect costs of no fewer than 6200 new and competing renewal awards and provide support for 13,320 noncompeting research projects. The bill also contains $199 million for research on acquired immune deficiency syndrome and funds for small instrumentation grants to be used for the purchase of equipment ranging in cost from about $5000 to $60,000.

Overall funding for the Department of Energy's research programs is also up in the House bill, 8% over the request and 6% over 1986, to just over $4 billion. However, a number of research programs face budget cuts in fiscal 1987. As approved by the House, funding for geothermal R&D is down 33% to $17.9 million, solar R&D is down 22% to $113 million, nuclear R&D

House okays rise in overall R&D funding

$ Millions	1987 Appropriation	1987 Request	1986	% difference Appropriation-Request	% change 1986–87
NIH	$ 6,152.8	$ 5,079.1	$ 5,259.7	21%	17%
Energy	4,044.5	3,734.1	3,799.5	8	6
Energy supply R&D	**1,679.9**	**1,567.0**	**1,660.4**	**7**	**1**
Supporting research and technical analysis	582.7	524.0	495.4	11	18
Magnetic fusion	358.0	333.0	365.5	7	−2
Nuclear	330.9	330.9	375.7	−7	−12
Environment	249.0	272.7	223.7	−9	11
Solar	113.4	72.3	144.6	57	−22
Electric energy systems and storage	28.0	16.2	28.8	73	−3
Geothermal	17.9	17.9	26.7	—	−33
Weapons R&D	**1,155.4**	**1,239.9**	**1,015.4**	**−7**	**14**
General science and research	**738.4**	**773.4**	**665.9**	**−5**	**13**
Fossil R&D	**314.5**	**82.8**	**2,096.9**	**280**	**6**
Conservation R&D	**156.3**	**71.2**	**170.9**	**119**	**−9**
NASA[a]	3,197.0	3,184.4	2,771.5	—	15
Conduct of R&D	3,020.7	3,003.1	2,638.2	1	14
R&D facilities	166.3	181.3	133.3	−8	25
NSF[a]	1,549.3	1,685.0	1,457.4	−8	6
Research and related activities	1,333.3	1,479.0	1,294.1	−10	3
Antarctic programs	117.0	117.0	110.1	—	6
Science education activities	99.0	89.0	53.2	11	86
Commerce	1,253.7	1,070.1	1,296.6	17	−3
NOAA	1,044.7	836.5	1,097.2	25	−5
NBS	114.0	124.0	118.4	−8	−4
PTO	95.0	109.6	81.2	−13	17
USDA	945.9	882.2	889.4	7	5
Agricultural Research Service	536.7	513.0	487.0	5	10
Cooperative State Research Service	269.1	246.3	276.1	9	−3
Forest Service research	129.2	111.5	125.5	16	3
National Agricultural Library	10.9	11.4	10.8	−4	1
EPA R&D[a]	288.0	295.2	324.6	−2	−11
TOTAL	$17,431.2	$15,930.1	$15,808.7	9%	10%

[a] Funding level approved only by House Appropriations Committee. **Note:** All figures are estimates.

is down 12% to $331 million, and conservation R&D is down 9% to $156 million.

The House provided $583 million for DOE's supporting research and technical analyses (SRTA) programs in fiscal 1987, 11% more than requested and 18% more than in fiscal 1986, with all of the SRTA subprograms receiving increases over fiscal 1986 funding levels. The lone SRTA subprogram supported at less than the Administration request is chemical sciences, for which a 10% increase had been sought. The House allowed only a 4% increase to $96 million.

The total of $59 million above the budget request that the House allocated for SRTA is more than accounted for by the $70 million that the Appropriations Committee added to the request for construction projects at eight institutions. Those include $16.3 million for the Energy Research Complex at the University of South Carolina; $14.8 million for an energy demonstration project at St. Christopher's Hospital for Children in Philadelphia; $12.3 million for the Center for Nuclear Imaging Research at the University of Alabama, Birmingham; $6 million for the Center for New Industrial Materials at Iowa State University; and $4 million for the National Center for Chemical Research at Catholic University in Washington, D.C. An amendment offered on the House floor to delete funding for the projects was defeated 315 to 106.

Other funding items approved by the House include a 10% increase over current funding to $537 million for the Agricultural Research Service, a 3% decrease to $269 million for the Cooperative State Research Service, a 5% decrease to just over $1 billion for research by the National Oceanic & Atmospheric Administration, and a 4% decrease to $114 million for the National Bureau of Standards.

Awaiting a floor vote at press time was the HUD-Independent Agencies appropriation bill that sets funding for the National Science Foundation, National Aeronautics & Space Administration, and the Environmental Protection Agency. The Appropriations Committee reduced the budget request for NSF 8% to $1.5 billion, leaving it with a 6% increase over current funding levels. Still, the committee says in its report on the bill that the increase represents the largest single increase recommended in 1987 for the operating programs of any major agency carried in the bill. The request for research and related activities was trimmed 10% to $1.3 billion, a bare 3% increase over current funding. The committee says it expects NSF to apply any reductions on a relatively equal basis. However, the committee provided $99 million for NSF's science education programs, an amount that is 86% above current funding and 11% more than requested.

The committee approved a 15% increase to $3.2 billion, just slightly more then requested, for NASA's R&D programs, while cutting EPA's R&D programs 11% to $288 million, 2% less than requested. The committee cut $6 million from EPA's in-house R&D budget. In its report the committee explains its actions by saying that "the 1987 request proposes a 10% reduction in extramural research but only token cuts in internal R&D resources. The committee has made this reduction to preserve the current balance of intramural and extramural R&D until the agency [EPA] develops the necessary management tools to make research activities more responsive to program office needs and to Congress."

The committee's decisions can, of course, be reversed by the full House and by the Senate. However, rather than adding money to appropriation bills, the House has been deleting money from them, and the Senate is likely to be equally tight fisted. Given that the latest deficit estimate is $230 billion, Congress will have to slash the budget by $86 billion if the mandatory fiscal 1987 deficit target of $144 billion set by the Gramm-Rudman-Hollings law is to be met. The Senate has devised a plan for reinstating the automatic across-the-board cuts provided for in that law. The House has not yet approved the plan. But however one looks at it, fiscal 1987 is not a good year to start with a low-base budget.

Janice Long, Washington

Federal Alert—new regulations

This C&EN listing highlights regulations published in the Federal Register *from July 7 through July 31. Complete information is available on the appropriate page number.*

PROPOSED

Environmental Protection Agency—Terminates investigation of occupational exposure to toluenediamines, concluding any such risk is more appropriately handled by OSHA (July 10, page 25070).

Revises and requests comments on requirements for analysis of total contaminants in groundwater; comments by Sept. 22 (July 24, page 28632).

Recommends limiting exposures to radiofrequency radiation; comments by Oct. 28 (July 30, page 27318).

Food & Drug Administration—Implements regulations for patent extensions for human drug products, food additives, color additives under Patent Term Restoration Act; comments by Oct. 9 (July 11, page 25338).

National Oceanic & Atmospheric Administration—Regulates licenses and permits for commercial recovery of deep seabed hard-mineral resources; comments by Oct. 23 (July 25, page 26794).

Occupational Safety & Health Administration—Recommends new performance-based standards to protect laboratory workers from toxic chemicals; comments by Oct. 22 (July 24, page 26660).

FINAL

Energy Department—Sets new terms for uranium enrichment services for civilian customers to help keep U.S. competitive in world market; effective Oct. 1 (July 29, page 27132).

Environmental Protection Agency—Requires specific health-effects tests by manufacturers and processors of certain chlorinated benzenes; effective Aug. 21 (July 8, page 1986).

Allows owners of hazardous waste landfills to use "corporate guarantee" to comply with liability insurance requirements; effective Sept. 9 (July 11, page 25350).

Revises regulations on primary containment vessels, release response, and closure requirements for hazardous waste storage and treatment tank systems; various effective dates (July 14, page 25422).

Food & Drug Administration—Clarifies whether presence of sulfiting agents must be included on food labels; effective Jan. 9, 1987 (July 9, page 25012).

Nuclear Regulatory Commission—Releases policy for regulation of advanced-technology nuclear power reactors; effective Aug. 7 (July 8, page 24643).

Dow Chemical photo

Engineering Plastics: More Products, More Competition

David Webber, C&EN New York

General Electric has introduced more new engineering plastics during the past four years than in any other period in the company's history. That spurt of innovation by the engineering resins pioneer and—according to many—leader, typifies the industry in the 1980s. "We've seen more product proliferation in the past few years than ever before," says Virginia W. Donohue of GE Plastics.

This is typical of the entire business of noncommodity plastics—including resins, alloys, blends, and composites with superior properties of impact resistance, heat resistance, and stiffness. It is in a period of intense activity. Not only are manufacturers churning out more new products and more modified versions of existing products, but more companies are entering the field. To beef up their offerings, producers are devoting greater resources to their research and development and technical service operations. At the same time, they are also turning to product line acquisitions, joint ventures, licensing, and other business relationships as never before.

To the greatest extent, this surge in activity reflects the expansion of the market for materials with ever-higher performance characteristics. Between 1983 and 1984, for example, U.S. production of a cross-section of major engineering resins increased 21% to 878 million lb, according to the Society of the Plastics Industry's most recent statistics. Between 1974 and 1983, by comparison, production grew at a com-

Donohue: dividing lines are gray

pound annual average rate of less than 7%.

This growth is occurring as downstream manufacturers become increasingly willing to spend more on raw materials to answer higher performance requirements in such major end-use industries as automobiles, packaging, electronics, computers and business equipment, aerospace, and medical supplies. However, as the expanding market attracts more players, producers are finding they must be more innovative to differentiate their products from those of their competitors. Consequently, the industry trend has been not just to develop more new products but also to tailor them more to specific end uses.

Meanwhile, engineering plastic products are under price pressure from upgraded commodity resins like polypropylene, polystyrene, and acrylonitrile-butadiene-styrene (ABS), which are taking away business in applications where high-performance requirements are more marginal. As a result, engineering plastics producers are working on ways to cut the ultimate expense of using their product for customers—if not in the price of the plastic then in the cost of processing it.

At the same time that vistas of enormous new markets are opening up to producers—in the potential, for instance, for thermoplastic exterior body panels for automobiles and for rigid plastic food packaging—the promise of greatly increased use of plastics in consumer products is heightening interest in the issue of recycling. Spurred by the tremendous success of polyethylene terephthalate (PET) beverage bottles, legislators, government officials, and environmentalists are worried that vast quantities of engineering plastic waste are likely to be added in the future to the existing plastic disposal problem. They want to ensure that consumer plastic scrap is not just dumped or burned. Industry, in an effort to work out methods to reclaim the materials on a basis more economical than incinerating them for their fuel value, is examining practical problems ranging from how to collect plastic scrap to how to separate the different resin components.

As engineering plastic products have become more specialized, manufacturers have converted en masse to the "get close to the customer" creed that has become the mid-decade slogan for researchers and marketers in the chemical and polymer industries. Producers of engineering plastics—as well as manufacturers of adhesives, coatings, and other products—have been flocking to Detroit, for instance, where they are busily establishing technical service laboratories and demonstration plants in their efforts to woo the automobile makers. Companies eyeing the mammoth packaging market, where commodity resins are big but engineering plastics are still relatively tiny, are reaching beyond their immediate customers—package fabricators—in their research into market needs. Instead, they are asking food companies and, in some cases, the general public what new packaging developments would be welcome.

Eidman: trying to determine needs

"We've been trying to determine the needs of converters and end-users in both the food and nonfood areas to let them determine where we place the emphasis in our research efforts," says Richard A. L. Eidman, Du Pont product manager for Selar barrier resins and Bynel coextrudable adhesive resins, both of which are used in packaging.

Dow Chemical, a relatively recent entry in the engineering plastics field, hopes that better knowledge of downstream needs will help it catch up to GE, Du Pont, and other industry leaders. "We're looking for trends on the level of our customer's customer to help us determine what our primary customers must do," explains Robert Baughman, Dow's general manager for specialty plastics. "Now we can go through what we learn from secondary customers and try to determine if there truly is an unmet need out there or if it is just Dow's feeling that there is one."

As more products have entered the engineering plastics end-use marketplace—including engineering resins, alloys, blends, copolymers, and enhanced grades of commodity resins—producers find themselves faced with the problem of defining an engineering plastic.

"A combination of things has made the dividing lines somewhat gray," remarks GE's Donohue, who is manager of business development and the planning operation for the plastics division. "It used to be easy to divide thermoplastics between commodities and engineering resins on the basis of performance and specifications. With what is happening today in blend work, however, and with more producers, there are a lot of unresolved issues."

The lack of uniformity in the way people apply a number of basic terms does not help resolve this definitional ambiguity. The broadest definition of engineering plastics

embraces everything above commodities, so to speak. In that sense, the term applies to workhorse engineering thermoplastics like polycarbonate and polybutylene terephthalate, to more specialized engineering resins like polyphenylene sulfide, polyether ether ketone, and liquid crystal polymers, and to alloys of materials like polycarbonate and polybutylene terephthalate.

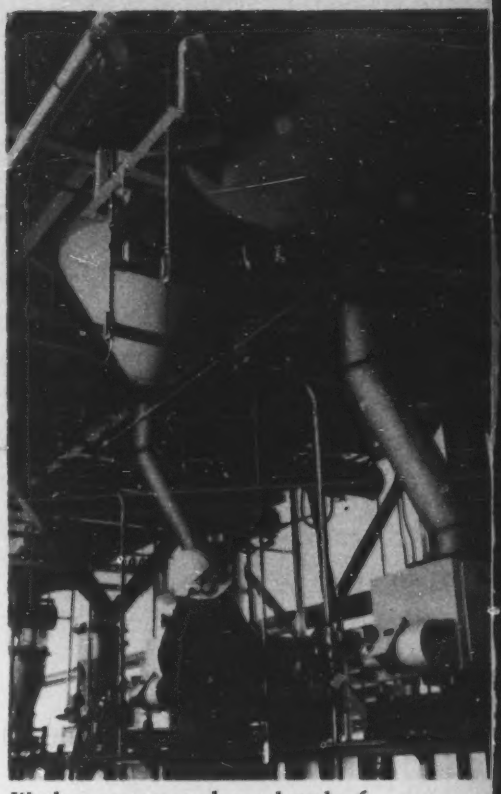
Narrower definitions separate products like polycarbonate from higher-performance plastics. At Charles H. Kline Inc., for example, all plastics are divided, for purposes of categorization, into three parts—tonnage plastics, specialty plastics, and combined materials. The Fairfield, N.J., research house drafts its definitions on the basis of price, volume, and application. Engineering thermoplastics form a subcategory of specialty plastics along with a second subcategory that Kline calls high-performance plastics.

The defining criteria break out along the following lines, according to Kline vice president Thomas E. Galvanek. Tonnage plastics, generally referred to as commodities, are characterized by high capital intensity, relatively low R&D costs, an emphasis on process development, little need for knowledge of end-use industries, great need for vertical integration in raw materials, and small product differentiation. Growth is relatively slow, and prices are generally less than $1.00 per lb.

Engineering thermoplastics, by comparison, are characterized by moderately higher R&D costs, lower capital intensity, lower sales tonnage, a greater need for knowledge of end-use industries, and less need for a raw material base. Prices typically range from $1.00 to $4.00 and more per lb.

In the Kline definition, high-performance plastics are high-risk businesses in which total demand is low but sales revenues are high, R&D costs are high, capital intensity is lower, and the need to know end-use industries is higher than in the case of commodities but lower than in the case of engineering thermoplastics. Volume growth is high, ranging from 10 to 20% per year, and prices range from $3.00 to $30 and more per lb.

Kline's third category, combined materials, includes blends, alloys, and reinforced plastics. Such businesses, Galvanek says, are characterized by low capital costs, because the equipment to produce the component materials is generally already in place. Some sort of mixer may be all that is required. But, he says, combined materials producers must acquire a thorough knowledge of their end-use markets, because they are looking for niches in which they can fill a performance gap at an intermediate price. As a result, combined materials are typically extremely tailored to a specific use, and producers must provide a great amount of technical service and development.



Worker processes enhanced grade of ABS at Dow Chemical's new Midland, Mich., production facility

Perhaps the least resolved aspect of the definition debate concerns enhanced grades of commodity resins. ABS, for example, is a commodity now available in versions whose performance makes them very much like engineering resins.

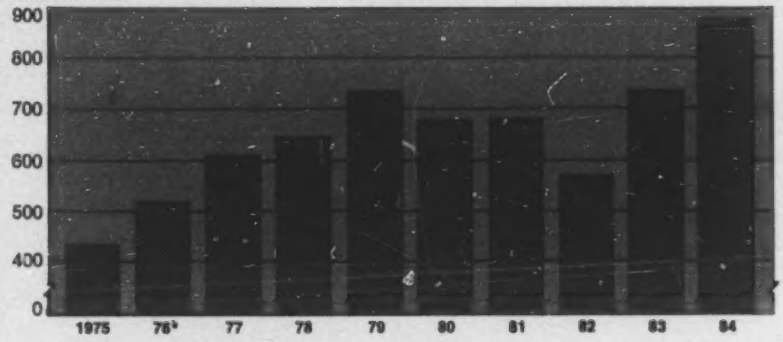
Dow, for example, which is trying to shift its product base in plastics from large-volume commodities to engineering thermoplastics and specialties, places both ABS and high-impact, high-gloss, and ignition-resistant grades of polystyrene alongside the company's polycarbonate and weatherable polymer lines in its engineering thermoplastics category.

At the same time that a burgeoning product mix has made definitions more vague, consumers of engineering plastics are putting increasing pressure on producers to tailor products to their precise needs. "As end-users have gotten more used to engineering plastics, they have become more sophisticated," GE's Donohue says. "They are more price- and quality-oriented. They have more knowledge about alter-

GE engineer molds prototype computer housing parts of modified PPO

CIRCLE 20 ON READER SERVICE CARD →

Engineering resins output has doubled since mid-1970s



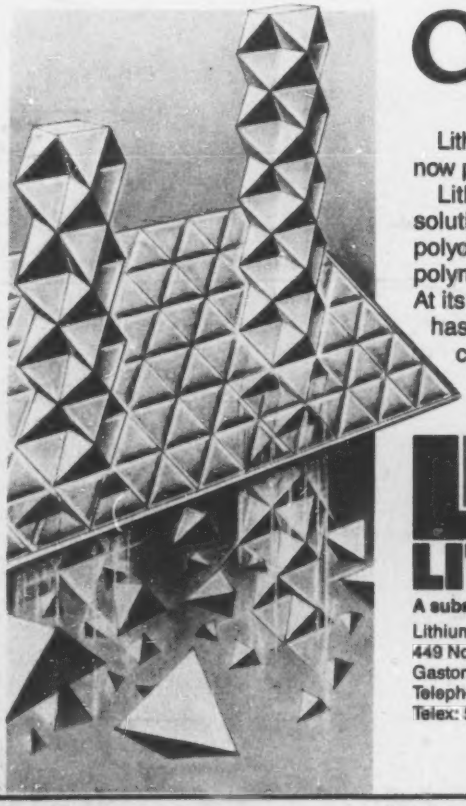
a Annual U.S. production of acetal, polycarbonate, polyphenylene sulfide, polysulfone, modified polyphenylene oxide, polyimide, and polyamide-imide engineering resins. b Estimated.
Source: Society of the Plastics Industry as compiled by Ernst & Whinney

native materials, so they have a greater ability now to make decisions between properties and price."

All these factors combined form the driving forces in the engineering plastics business today. More sophistication on the part of end-users has opened up opportunities for combined materials and upgraded commodity resins that can offer somewhat lesser but adequate performance at a lower cost. The proliferation of products that has followed both that trend and the increasing demand for the highest-performing plastic materials has created a large degree of overlap between products. A variety of plastics, for instance, may possess the required heat-resistance properties for a certain application but will differ in terms of other performance properties, processing, and price.

In this more complicated world, product differentiation has become the byword for companies. To better differentiate themselves from their competitors, engineering plastics producers have adopted two key strategies: broadening their product portfolio and bolstering their technical service operations.

The two strategies are linked by the increased need to give those more sophisticated end-users exactly what they need. A broader product portfolio means more than just offering a wider range of off-the-shelf materials to potential customers. A broader base of materials available for blending and alloying



CATALYSIS

Lithco, long a world leader in the manufacture of lithium products, now produces an expanded range of fine organometallics.

Lithco's magnesium alkoxides are available in hydrocarbon solutions and offer distinct advantages in the manufacture of polyolefins. Lithco also provides many other organometallics for polymerization, including alkyllithiums and dibutylmagnesium. At its new, multi-million dollar facility in North Carolina, Lithco has the capacity to custom synthesize catalytic agents to customer specifications.

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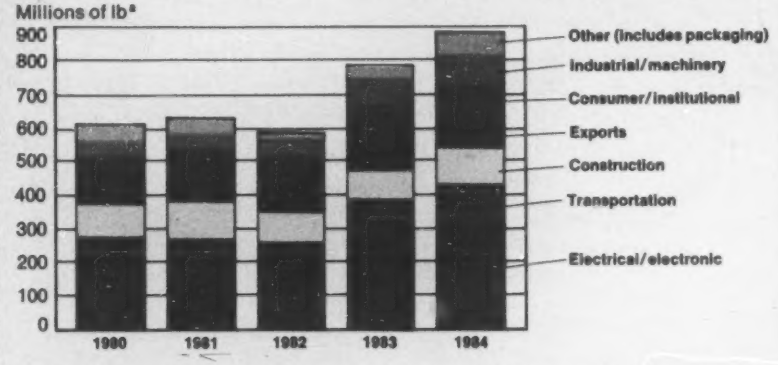
CIRCLE 24 ON READER SERVICE CARD

Electrical/electronic uses lead engineering resin markets



a Estimated U.S. sales and captive use for acetal, polycarbonate, polyphenylene sulfide, polysulfone, modified polyphenylene oxide, polyimide, and polyamide-imide engineering resins.
Source: Society of the Plastics Industry

makes it easier to tailor products to meet specific requirements.

"We are increasingly called on to tailor materials to customer needs," points out James T. Hill, manager for electronics in Du Pont's polymer products department. "A key strength for us is that we have a wide spectrum of materials to draw from."

The job of properly directing that strength at the marketplace falls to the technical service operation. At Du Pont, as at other companies, such services have been substantially expanded in recent years.

"Because of the broad proliferation of products and the significant areas of overlap between different polymer families, we are focusing heavily on the area of providing more than just a bag of resin," says John F. Wahl, national development manager for the engineering polymers business at Du Pont. "We're offering a full range of services: design support, engineering support, prototyping, and analysis of a product's economics, all the way to processing and fabrication. It's a complete systems approach."

The growth of the service element in the engineering plastics business is exemplified by the stampede of producers to establish new or expand existing technical service centers in the Detroit area in the past two years. Du Pont, for example, is building a multimillion-dollar technical service laboratory at its one-year-old corporate automotive

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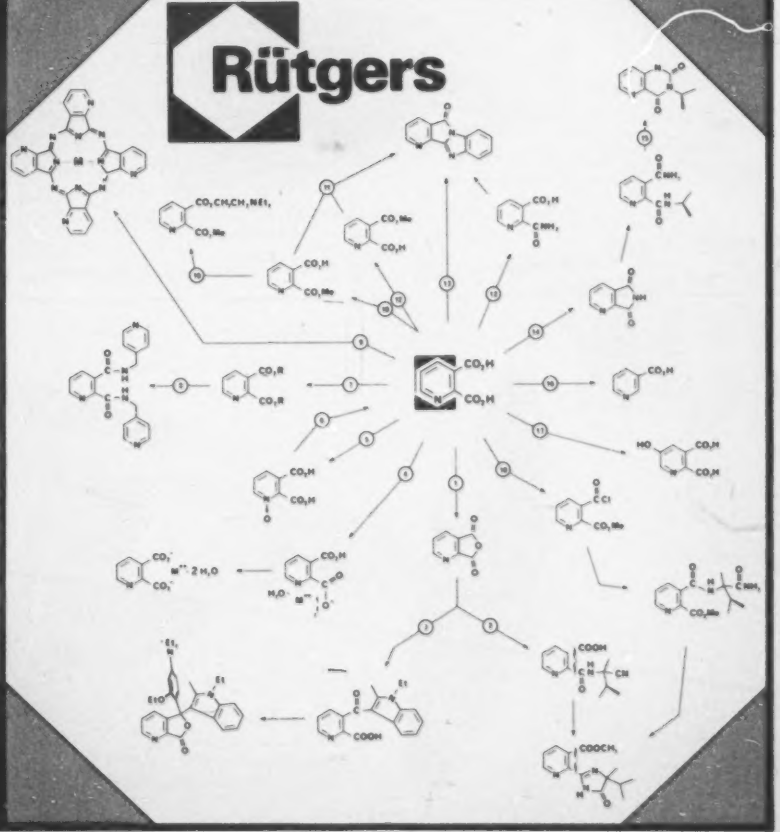


CIRCLE 29 ON READER SERVICE CARD

Engineering resins are generally used in conditions of high heat, impact, or moisture

Resin	Typical applications
Acetal	Sinks, faucets, electrical switches, gears, aerosol bottles, meat hooks, lawn sprinklers, ballcocks, shaver cartridges, zippers, telephone push buttons
Polycarbonate	Helmets, power tool housings, battery cases, safety glass, automobile lenses, 5-gal bottles
Polyphenylene sulfide	Electrical connectors, coil forms, lamp housings
Polysulfone	Electrical connectors, meter housings, coffee makers, camera bodies, automobile switch and relay bases, light-fixture sockets, fuel cell components, battery cases, medical supplies
Modified polyphenylene oxide	Automobile dashboards, pumps, shower heads, plated automobile grilles and trim, appliance housings, wiring splice devices, protective shields
Polyimide	Radomes, printed circuit boards, turbine blades
Polyamide-imide	Valves, gears, pumps, high-temperature magnet wire enamels

Source: Society of the Plastics Industry

development center in Troy, Mich., for application development of engineering polymers. The lab, due to be completed late in 1987, will include a 4000-ton injection molding machine, the sort of investment that companies are now making in their efforts to woo automobile design engineers.

In June, Celanese Engineering Resins, a subsidiary of Celanese, announced it will open an automotive development center in the Detroit area early next year. Celanese says that the automotive industry is the largest single market for its existing engineering thermoplastics—Celcon acetal copolymer, nylon, and Celanex thermoplastic polyester. The company also expects the auto industry to be a major user of a group of new resins that Celanese has either developed, acquired, or licensed in the past two years.

The new center will contain design and analytical laboratories with capabilities for computer-aided design and finite element analysis. There also will be injection-molding equipment and a parts-testing lab for end-use evaluation.

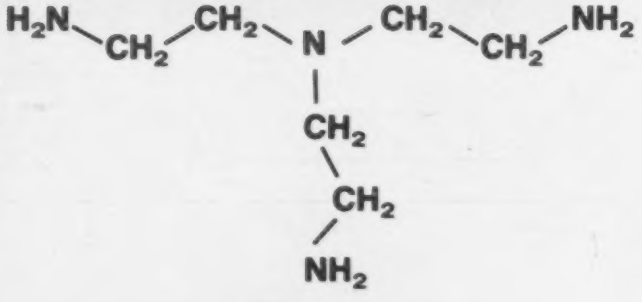
"Given the size of the market, and considering the expanded line of materials we're now offering, we definitely need a stronger presence in Detroit," explains John B. Downard, general manager of Celanese Engineering Resins. "The automotive technical center will do just that."

Earlier this year, Monsanto established an automotive marketing group in Detroit and is planning to build an automotive support facility by sometime in 1987. "Issues and opportunities relating to the automotive market are now addressed here in Detroit," says William J. Ginter, director of the new group. "Sales, marketing, and development personnel for plastic products sold to the automotive industry will now report directly to this office."

The other key element in the product differentiation strategy—broadening product portfolios—has also resulted in a flurry of activity in recent months. That activity has featured, as well as new product introductions, a surge in acquisitions, joint ventures, licensing agreements, and other business arrangements.

Celanese Engineering Resins presents a good example of a company moving rapidly to broaden its product line through a variety of measures. Last month, the company purchased the engineering resins business of GAF Corp. for an undisclosed amount. The GAF lines consist of polybutylene terephthalate (PBT) and thermoplastic polyester elastomers.

Unlimited Reactions



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Most resin types have just a handful of producers

Company	Location	Tradename	Annual capacity[a] (millions of lb)
Acetal			
Celanese	Bishop, Tex.	Celcon	145
Du Pont	Parkersburg, W.Va.	Delrin	135
Arylate			
Amoco Chemicals[b]	Marietta, Ohio	Ardel	13
Celanese[c]	Grand Island, N.Y.	Durel	na
	Corpus Christi, Tex.	Durel	na
Polybutylene terephthalate			
Celanese	Bishop, Tex.	Celanex	70
	Calvert City, Ky.[d]	Gafite, Gaftuf	10
General Electric	Mt. Vernon, Ind.	Valox, VCT	130
Polycarbonate			
Dow Chemical	Freeport, Tex.	Calibre	30
General Electric	Mt. Vernon, Ind.	Lexan	300
Mobay	Cedar Bayou, Tex.	Merlon	160
Polyether ether ketone			
Amoco Chemicals[b]	Marietta, Ohio	Kadel	na
ICI Americas	Wilmington, Del.	Victrex	>1
Polyimide and polyamide-imide			
Amoco Chemicals	Joliet, Ill.	Torlon	na
Du Pont	Beaumont, Tex.	Kapton	na
	Circleville, Ohio	Kapton	na
	Newark, Del.	Vespel	na
General Electric	Mt. Vernon, Ind.	Ultem	na
Polyphenylene oxide			
General Electric	Selkirk, N.Y.		na
Polyphenylene sulfide			
Celanese[e]	na	Fortron	na
Phillips Chemical	Borger, Tex.	Ryton	12
Polysulfone			
Amoco Chemicals[b]	Marietta, Ohio		20
ICI Americas	New Castle, Del.		>1

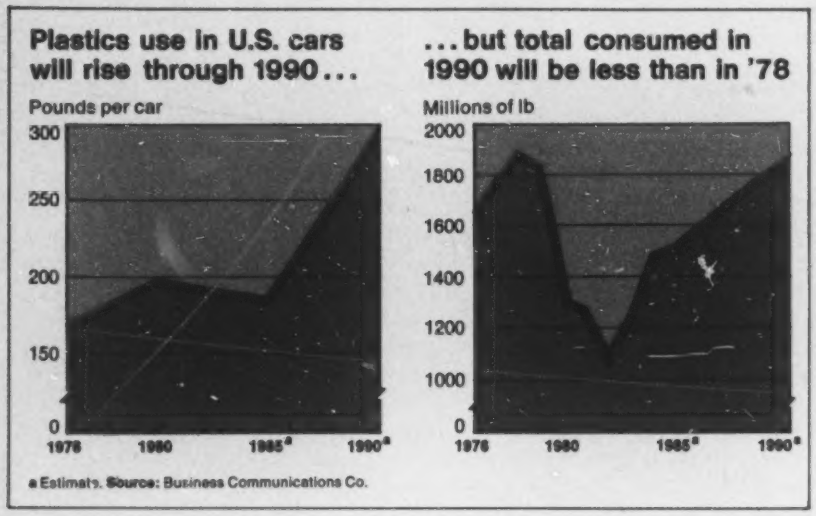
a Estimated. b Purchased from Union Carbide in June 1986. c Purchased from Occidental Chemical in May 1985. d Purchased from GAF in July 1986. e Currently selling material imported from Kureha Chemical of Japan. Plans to build U.S. plant in future. **Note:** Representative list of producers. na = not available. **Source:** SRI International

Last month, Celanese also signed an agreement with Kureha Chemical Industry Co., of Japan, giving Celanese exclusive North American sales rights as well as partial rights in Europe and Latin America to Kureha's polyphenylene sulfide (PPS) engineering resin. The arrangement makes Celanese the first U.S.-based competitor for Phillips Chemical's Ryton PPS resin. Initially, Celanese will market PPS using

Polyphenylene sulfide use to grow 15% annually

Millions of lb	Consumption 1985[a]	Share of total	Consumption 1990[a]	Share of total	Annual growth rate, 1985–90
Electrical/electronics	3.2	33%	12.5	30%	15%
Mechanical/industrial	2.3	23	8.5	20	14
Appliance	0.9	9	2.2	5	9
Transportation	0.9	9	4.0	10	15
Chemical processing	1.0	10	3.3	8	13
Miscellaneous industrial	1.0	10	2.2	8	12
Powder uses	0.5	5	0.8	2	5
Composites	0.1	1	2.0	4	35
Fibers	—	—	1.0	2	—
Film/sheet	—	—	4.5	11	—
TOTAL	9.9	100%	42.0	100%	15%

a Estimated. Source: Celanese



resin imported from Kureha, but once sales become large enough, Celanese will build a U.S. production facility in cooperation with the Japanese firm, says Celanese Engineering Resins vice president Thomas C. Bohrer.

Also last month, Celanese established a sales, marketing, and technical support company for engineering plastics in West Germany. The move reflects the increasingly global nature of the engineering plastics industry.

In a different type of arrangement, General Electric Plastics and PPG Industries last month formed a 50/50 joint venture called Azdel Inc. to make composites by combining PPG's expertise in glass-reinforced polypropylene sheet with GE's engineering plastics know-how. Although not so limited, the venture is seen as an intensification of GE's effort to come up with an engineering plastic-based material that Detroit could choose to replace both stamped steel and thermoset materials like fiber-reinforced polyester in large exterior auto panels.

"We see more possibilities of partnerships and joint ventures in our cards," remarks GE's Donohue. "The premise is that if we share expertise, we all gain more. The PPG venture is an excellent case in point."

In the acquisition arena, Amoco Chemicals' subsidiary Amoco Performance Products closed its purchase of Union Carbide's engineering polymers and advanced composites businesses in June. Carbide needed cash to pay off debts incurred by its defense against GAF's takeover attempt last December, while Amoco Chemicals, according to president Robert D. Cadieux, wanted to grow "in areas that are compatible with our current chemical operations and in which we have a long-range strategic interest."

The acquisition made Amoco Performance Products in a stroke a major player in the engineering plastics business. Previously, the company's presence was greatly based on one product—Torlon, a polyamide-imide resin used in composite form in racing car engines, fasteners in the space shuttle, and a developmental hydraulic pump used by the Navy for undersea salvage. With the acquisition, Amoco gained polyarylate, polyether ether ketone, polysulfone, and other resins as well as Carbide's line of rayon-, pitch-, and polyacrylonitrile-based carbon fibers.

This willingness by companies to spend substantial amounts of money—whether to broaden product lines, to increase customer services, or both—ultimately stems from perceived opportunities in end-use markets. In the automotive industry, for

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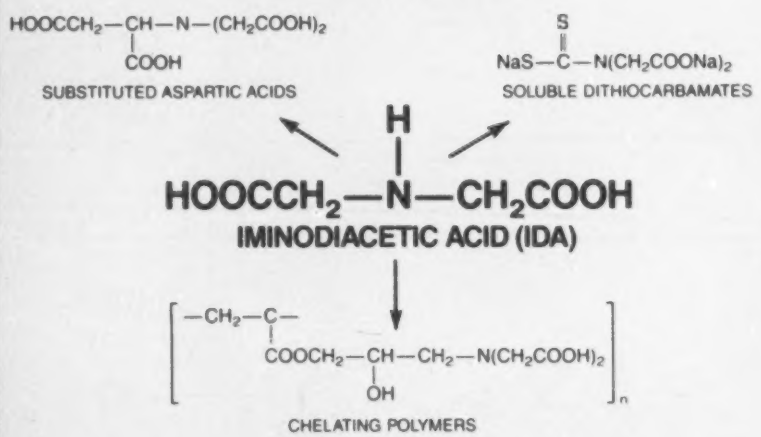

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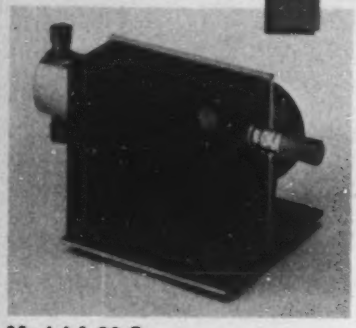

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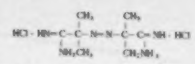

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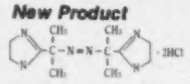

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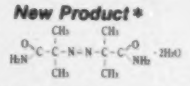

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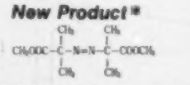

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Product Report

Electrical uses dominate polysulfone resins market

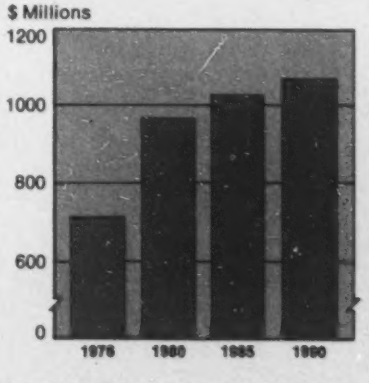
Millions of lb	Consumption	Share of total
Electrical/electronics	5.0	37%
Consumer/institutional	2.4	18
Transportation	2.0	15
Medical	1.4	10
Industrial	1.2	9
Other	1.5	11
TOTAL	13.5	100%

Note: Estimated 1985 U.S. consumption. **Source:** SRI International

example, the nature of those opportunities has been changing. A decade ago, says Nicholas G. Fountas, senior plastics consultant at Charles H. Kline, the impetus for using plastic in automobiles stemmed 80% from the desire to reduce a car's overall weight. Today, he says, the impetus is divided more or less evenly between weight-reduction and other issues like performance and processing economics.

For example, a major trend in Detroit now—as well as in the major appliance and other industries—is parts consolidation. Automobile design engineers reason that if they could replace a part assembly that involves, say, seven or eight individual cast components with a single molded part, they could cut the labor element of that part, while probably reducing weight and perhaps improving performance properties at the same time. Engineering plastics producers are hoping

Revenue growth for auto resins will be restrained



Note: Value of plastic resins in automobile applications. **Source:** Business Communications Co.

High performance pipe is growing market for Amoco Chemicals' polysulfone

to cash in on this way of thinking, which is expected to become an increasingly more important feature of the auto industry's attempts to shave costs in order to regain its competitiveness with Japanese and other overseas car manufacturers.

Another important aspect of Detroit's thinking these days is design flexibility. It costs more to retool machinery for metal than for plastic parts, but during the U.S. auto industry's heydey, when model production runs were lengthy, that cost was easily justifiable. Now, with shorter model runs, retooling is required more frequently. As a result, the ability to regear more cheaply adds a production economics rationale to the plastic producers' armamentarium of arguments.

Detroit is also scrambling to meet upcoming deadlines for corporate average fuel economy ratings. Where manufacturers originally concentrated on weight reduction to improve fuel ratings, they are now focusing increasingly on aerodynamics to do so. "A major design trend is the move to a more slippery profile," points out Kline's Fountas. "Plastics work well for sleek contours, better than most metals. It's possible to form plastics into very intricate shapes."

Plastics also continue to replace metal in under-the-hood applications, particularly as more high heat resistant materials become available. And producers are paying lots of attention to the potential for engineering thermoplastics in exterior panels. Today, there are relatively few autos made in the U.S. with plastic body panels, and all those, as is the case with General Motors' Corvette and Pontiac Fiero, are fiber-reinforced polyester. The exterior role of engineering thermoplastics, to date, has been mostly limited to smaller external parts, such as the plastic alloy bumper on the Ford Aerostar van.

Still, the promise is there. General Motors, for example, predicts that it will be manufacturing a million plastic-body automobiles in 1990, up from 150,000 this year. Engineering plastics producers want to make sure that their products play a major part in the composition of those cars. "It represents a tremendous opportunity in terms of the size of the market," says GE's Donohue.

Their increased presence in the Detroit area is testimony to that resolve. Engineering plastics makers know they must use all the tools available to them, up to and including actually fabricating automobile parts from their materials in pilot plants, to convince automotive design engineers to select their product. The opportunities alone do not explain the new round of investment in automotive-oriented facilities, however. Detroit, knowing it needs major improvements, also has

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become far more accommodating than during its more imperious past.

"General Motors, for instance, is now telling resin producers, 'If you can get us the materials at the right price, we'll give you longer contracts,'" points out Peter Mooney of Business Communications Co., a research company. "That's better than before, when the car companies were buying plastics but changing suppliers every few months. The plastics procurement policies in Detroit have become a little more humane, because of the great pressures the car companies are under. As a result, a lot of plastics companies that wouldn't go near Detroit before will now. Detroit needs their input."

In the electrical/electronic segment of the engineering plastics market—the largest at about a third of the overall business—a variety of trends are increasing demand for the highest-priced materials at one end and fostering erosion of those materials' hold on other applications at another end. One constant trend in the electrical/electronics area is size reduction. As products are made smaller, electronic engineers, to get more performance out of the same size component, place the pins on electronic interconnectors closer and closer together. That improves performance, but coincidentally creates a greater amount of heat.

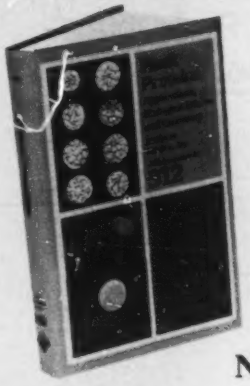
"Miniaturization of the electronic portions of devices raises the density of those devices and increases the heat load," points out Du Pont's Wahl. "So there is a need for higher-temperature performance capability."

In another trend, component assemblers are using wave and vapor-phase soldering more frequently now, further increasing the need for heat-resistance."

Those changes are altering the material choices made by the electronics industry. Early on, points out Kline consultant Fountas, interconnectors were made with thermosetting resins. Those were replaced by nylons, but when nylons began to prove too moisture-sensitive in more critical applications, glass-reinforced polybutylene terephthalate began its move toward dominance. PBT is now preeminent

CIRCLE 20 ON READER SERVICE CARD →

Plant Proteins



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in interconnectors, but, Fountas says, increasing demands for heat-resistance and dimensional stability will begin to threaten PBT's position. He sees a move toward greater use of more specialized engineering thermoplastics like polyphenylene sulfide and liquid crystal polymers in the future.

Similarly, changes in the way circuit boards are made are affecting raw material selection. There, thermoplastics are just beginning to make their presence felt. Traditionally, circuit boards have generally consisted of epoxy-glass fiber laminates limited in shape to a planar configuration. Now, with advances in high-temperature thermoplastics, circuit board manufacturers are moving toward molded, nonplanar shapes that can both perform the function of a circuit board and, in some cases, a structural part. "Circuit boards will begin to have a functional purpose, as in the housing for a motor part," points out Du Pont's Hill.

In the computer housing segment, development has run into the downturn in the computer market, coupled with the shifting overseas in recent years of a lot of molding operations as manufacturers have sought to reduce assembly costs. At the same time, many overseas molders are using plastics from other than U.S. sources. Some analysts believe that some of those manufacturing operations eventually will return to the U.S. as companies automate more, but, in the meantime, the trend has hurt producers of polycarbonate and ABS resins used in computer housings.

In the beginning of the computer boom, most housings were made of GE's Noryl resin. Noryl was priced at a premium but possessed the heat properties and flame resistance that manufacturers needed. Since then, some manufacturers have switched to enhanced grades of ABS, saving 25 to 50 cents per lb on raw material costs in the process. Now, Fountas points out, ABS is beginning to lose ground to high-impact polystyrene that has been upgraded enough to earn a high enough Underwriters Laboratory rating for computer housing applications.

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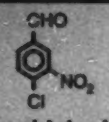

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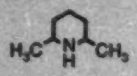

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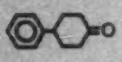
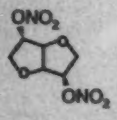
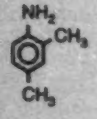


4-Phenylcyclohexanone

Isosorbide dinitrate (ISDN) mixtures with lactose etc., USP XXI

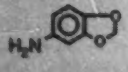


2,4-Xylidine and all other isomers



2-Ethylaniline and 4-Ethylaniline

3,4-Methylenedioxyaniline and N-Ethyl derivative



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CIRCLE 31 ON READER SERVICE CARD

high-impact polystyrene," Fountas remarks, "but some companies that make many terminals probably will. People are looking at it with great interest."

In the packaging arena, engineering themoplastics are still in their infancy. According to Society of the Plastics Industry estimates, just 2 million lb, or about 0.2% of entire U.S. engineering plastics consumption, went into packaging in 1984. But producers see trends emerging, in the consumer, processor, and retailer areas, that should greatly increase demand in coming years, especially in the food segment.

Demographic trends toward smaller and two-worker households are expected to increase the need for convenience in the form of such products as single-serving packages and what the industry calls "dual-ovenable" packages—containers that can be taken from freezer or cupboard, heated in either a conventional or microwave oven, and brought to the table. At the same time, processors and retailers are looking for better barrier properties in packaging plastics, so that more food products can be shipped and stored without refrigeration.

Those converging trends are expected to change the mix of materials used in making food packaging. "Ovenable trays now are mostly of the polyester variety. They are suitable for uses now, but mostly for frozen products," notes Du Pont barrier resin product manager Eidman. "With the trend to shelf-stable products, there must be an improvement in barrier characteristics. So polyester may still be involved in future packaging, but probably only as one layer."

Despite engineering plastics' small presence in packaging today, Du Pont expects substantial growth. The company estimates that about 17% of revenues to producers of packaging materials is accounted for by plastics today, Eidman says. By the end of the century, he says, some 42% of that total will come from plastics. "Of that," he says, "the growth will be primarily in barrier-type structures."

"We're getting out of the embryonic stage into a stage of rapid growth," he predicts. □

Computer Applications in the Polymer Laboratory

New!

Theodore Provder, *Editor*
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